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MEDICAL RESEARCH COUNCIL

The Exposure of the Population to Radiation from Fallout

A report to the Medical Research Council
by their Committee on Protection against Ionizing Radiations

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1. Introduction

The latest report of the Agricultural Research Council's Radiobiological Laboratory (Report ARCRL 11, 1964) gives an account of recent measurements of contamination of milk by various components of world-wide radioactive fallout. These levels and the levels of contamination of other articles of diet reported earlier in the Annual Report for 1962–63 of the Agricultural Research Council's Radiobiological Laboratory (Report ARCRL 10, Agricultural Research Council: London, 1963) are higher than those previously recorded. This situation was to be expected because of the scale of the nuclear tests carried out in 1961 and 1962. The possible radiation doses to human tissue which might result have been kept under review by the Medical Research Council, and the following represents an assessment of the likely maximum somatic radiation doses attributable to nuclear testing to date*.

Attention has been largely focused on strontium 90 because it continues to emit radiation for many years and, like its chemical analogue calcium, is retained for comparatively long periods in bone. This tissue at present receives the highest total radiation dose from the various components of fallout, and strontium 90 is the main contributor to this dose. In the present circumstances strontium 90 is regarded as the most important single component of fallout requiring consideration, and levels are highest in the bones of young children, who therefore merit special attention. For this reason the present assessment is concerned mainly with the concentrations of strontium 90 which may be reached in the bones of young children.

2. Derivation of 'Permissible Concentrations' of Strontium 90 in Human Bone

The criteria used in specifying maximum permissible concentrations of strontium 90 in the bones of the general population and of individuals in the population have been developed from recommendations which were designed to ensure the safety of workers exposed to radiation in the course of their occupation. For the latter purpose the International Commission on Radiological Protection has recommended 'maximum permissible doses' of radiation. These recommendations are based on the principle that occupational exposure should be so limited that it involves a risk which is not unacceptable to the individuals concerned. Any ill effects caused by these doses would be expected to be detectable only with great difficulty by statistical methods applied to large groups, if they were detectable at all.

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* The implications of genetically effective radiation doses from world-wide fallout have been extensively reviewed in the second report of the United Nations Scientific Committee on the Effects of Atomic Radiation (United Nations: New York, 1962). The present statement does not therefore attempt any further evaluation.

The mean genetic dose, attributable to nuclear tests to date, was about 10 millirem in 1963. This dose is about 8 per cent of that received from natural background radiation. The annual dose is expected to become progressively less in 1964 and subsequently, in the absence of further atmospheric nuclear tests.

In addition to making recommendations for the occupationally exposed, the International Commission recommended that individual members of the population should not be exposed to more than one-tenth of the limit set for radiation workers. It was further suggested that, for planning purposes, average somatic exposures for the population as a whole should not exceed one-thirtieth of those set for the occupationally exposed.

The Medical Research Council in their second report *The Hazards to Man of Nuclear and Allied Radiations* (Cmnd. 1225, H.M.S.O., London, 1960) accepted these concepts and in the light of available information specified the following limits for strontium 90 in bone: 200 pc Sr-90/g Ca* for individual members of the population irrespective of age, and 67 pc Sr-90/g Ca for the average over the whole population. The term 'maximum permissible concentration' was applied to these limits. The radiation dose rates to bone associated with these concentrations are 540 and 180 millirem/year respectively,† and about one-third of these values in bone marrow. For comparison, the average dose rate from natural background radiation to bone has been estimated at about 130 millirem/year.

Because a considerable interval of time elapses between the detonation of nuclear weapons and the attainment of the resultant level of strontium 90 in bone, the Medical Research Council further recommended that a reassessment of the situation would be required if the concentration in human bone, calculated as an average for any age-group of the population, including the groups of infants and young children, was found to be rising continuously and to have reached one-half of that recommended as the maximum permissible level for the population as a whole (i.e. 33 pc Sr-90/g Ca, the so-called 'cautionary level').

Some explanation may be needed of the reasons for setting more restrictive levels for the population as a whole than for individuals. Appreciable variations in exposure inevitably occur between members of any population. Thus, unless the average exposure of the population as a whole is kept below that specified for individuals, some unidentified persons might be exposed above this latter level. The limit set for individual members of the population may, therefore, be regarded as an important protection criterion. No value is specified as to the fraction of the population which can be exposed at this level, provided that the limit set as an average for the population as a whole is not exceeded.

3. Levels of Strontium 90 Measured in Bone to Date

The Medical Research Council publishes results of direct measurements of levels of strontium 90 in human bone at approximately six-monthly intervals (M.R.C. Monitoring Report Series, H.M.S.O.: London). The mean levels of strontium 90 recorded in bone in the age-group 1–2 years for the years 1959, 1960, 1961 and 1962 and the first half of 1963 have been respectively 3·9, 3·4, 2·5, 2·4 and about 4 pc Sr-90/g Ca; the mean results for all other age-groups have been below these values*. It is apparent that these levels are only small fractions of the maximum permissible level suggested for the general population (67 pc Sr-90/g Ca). Similarly, all the individual measurements given in the bone monitoring reports are small fractions of the recommended maximum permissible level for individual members of the population (200 pc Sr-90/g Ca).

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* picocuries (=micro-microcuries) of strontium 90 per gram of calcium.

† In their second report *The Hazards to Man of Nuclear and Allied Radiations* the Medical Research Council when considering dose in bone from beta-radiation equated millirads with millirems and the convention has been continued here.

There is, however, a considerable time-lag before the eventual bone levels which can be attributed to a particular series of nuclear tests in the atmosphere are reached. This is mainly due to the slow deposition of strontium 90 from the stratosphere, its subsequent passage through the ' food chain ', and its eventual incorporation into the human body. A further period of time is moreover required to collect and analyse sufficient bone samples to provide representative information. Thus the full effects of the 1961 series of nuclear tests are not yet fully reflected in the latest bone measurements and those of the 1962 series are only just becoming apparent. The possible levels of strontium 90 which may arise in bone in the future as a result of past weapons tests are discussed in Section 6.

4. Surveys of Environmental and Dietary Contamination

Country-wide Situation

In view of the inevitable time-lag before measurements in bone reflect the current situation, measurements of environmental and dietary levels of strontium 90 form a necessary complement to those on human bone, and in addition they provide important information on local variations in exposure.

The results of surveys of environmental contamination are published at regular intervals by the Atomic Energy Authority and the Agricultural Research Council. As is fully described in Reports ARCRL 10 and 11, a comprehensive scheme for monitoring levels of dietary contamination on a nation-wide scale is in continuous operation.

Local Variations

There are certain places in the country where the combination of unfavourable agricultural factors and high rainfall gives rise to higher levels of strontium 90 in foodstuffs than elsewhere. It may be inferred that any persons living consistently on the local produce of such places will eventually accumulate correspondingly higher levels of strontium 90 in their bones. These conditions are found only in sparsely populated areas of low agricultural productivity. The special sites referred to in Report ARCRL 11 were identified after extensive investigations by the Agricultural Research Council and the Agricultural Departments as places—frequently isolated farms—where conditions could be expected to give rise to maximum concentrations of strontium 90 in milk. It must be emphasized that these sites, where levels are unusually high, are not representative of the conditions generally prevailing in areas of high rainfall, or of the counties in which they are situated.

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* A larger number of samples from areas of higher than average rainfall have been deliberately included in the bone monitoring programme. Thus the mean values reported above are considered to be higher than would be observed if samples had been collected on a strictly representative basis.

The data presented in Report ARCRL 11 show that the average level of strontium 90 in samples of milk from all these sites throughout 1963 was some four times higher than the average for the country as a whole. The highest annual level anywhere recorded out of a total of 32 sites under special investigation is about eight times the country-wide average. This highest level has been taken for the purposes of the present assessment as being indicative of the worst conditions to be expected. It must also be emphasized that proportionately high levels of strontium 90 would not be reached in the bones of infants unless they consumed milk contaminated at such levels continuously for many months.

Owing to the very low infant mortality rate in this country, it has not been possible to make representative measurements on the bones of infants from these sparsely populated sites. Levels of strontium 90 in their bones have therefore been inferred on the basis of the levels recorded in milk.

5. Estimation of levels of Strontium 90 in the Bones of Infants from Measurements of Dietary Levels

It is well recognized that the ratio of strontium to calcium in bone is determined largely by the ratio of the two elements in diet, but in the passage from diet to bone there is appreciable discrimination against strontium relative to calcium. In their second report *The Hazards to Man of Nuclear and Allied Radiations* the Medical Research Council concluded that the average ratio of strontium 90 to calcium in bone would be one-quarter of that in diet, and the general applicability of this figure has since received support in the second report of the United Nations Scientific Committee on the Effects of Atomic Radiation (United Nations : New York, 1962).

There are however a number of uncertainties inherent in the estimation of future bone levels of strontium 90 from measurements of dietary levels, particularly in the case of infants and young children. The extent of the discrimination against strontium is not constant and there is evidence that it may be less in the very young. The interpretation of the relationships between levels in diet and those in bone is further complicated by the fact that the length of time for which both elements are retained in bone changes with age. There are also uncertainties about the actual diets and the origins of particular articles of diet consumed by infants and young children. It is, however, known from earlier investigations that milk has been the main source of both strontium 90 and calcium in the diet of these individuals. Although many aspects of the physiological relationships between dietary and bone levels of strontium 90 and calcium remain to be elucidated, the relationship observed between the ratio of these two materials in milk and that in bone provides an empirical basis for estimating the significance of current dietary measurements. Particular attention has been paid to the relationship observed between the ratio of strontium 90 to calcium in milk and that in bone in the first year of life; these observations show that in this country the ratio in bone is about one-quarter of that in local milk. To provide a valid basis for the assessment of contamination of bone resulting from dietary levels, an averaging period of one year has been adopted for the following calculations.

6. Estimated Levels of Strontium 90 in Bone Resulting from Nuclear Tests to Date

By using the figures given in Report ARCRL 11 for contamination of milk by strontium 90 throughout 1963, and taking the considerations in the preceding paragraph into account, it is estimated that the maximum level which could be reached in the bones of any individual infant continuously exposed to the most adverse local conditions to date would be about 50 pc Sr-90/g Ca (equivalent to a radiation dose rate to bone of about 140 millirem/year). On the same basis, the mean level of strontium 90 in the bones of young children in the population of any large region of the country is not expected to reach 10 pc Sr-90/g Ca (giving about 30 millirem/year), and the country-wide average will be not more than 7 pc Sr-90/g Ca (giving about 20 millirem/year).

It is expected that the bone levels for young children in 1964 will be substantially the same as those estimated above, and that in the absence of further atmospheric nuclear tests such levels will fall thereafter.

7. Estimation of Additional Radiation Dose to Bone from Different Components of Fallout

In making their recommendations on levels of strontium 90 in bone the Medical Research Council emphasized that account should be taken of substantial and persistent additional radiation doses from other sources. The problem of the manner in which other components of fallout add to the exposure of tissues is, however, a complex one. For example, some components of fallout give rise to irradiation of the body from within because of ingestion from diet (internal radiation) and others contribute to the overall radiation dose from outside because of their deposition on the ground (external radiation).

Additional Internal Radiation Sources

Caesium 137. Unlike strontium 90, caesium 137 is relatively uniformly distributed throughout the body and is retained for considerably shorter periods. It is therefore a considerably less persistent source of radiation in the body than strontium 90.

Like strontium 90, however, caesium 137 enters the diet of infants mainly through milk. The highest levels of contamination are observed where strontium 90 is also high. It is estimated that the maximum radiation dose from this source which could have been delivered to bone in any infant continuously exposed to the most adverse local conditions throughout 1963 would not have reached 40 millirem, or less than one-third of the total dose attributable to strontium 90 ingested during the same period. The corresponding country-wide average dose from this source should not reach 5 millirem. It is expected that, in the absence of further atmospheric nuclear tests, the doses from caesium 137 will be decreasing by the end of 1964.

Strontium 89 and Barium 140. Owing to its short physical half-life, strontium 89 only gives a significant tissue dose during the year following a weapons test. On the basis of the available data for 1963, it is estimated that the maximum dose to bone in any infant continuously exposed to the worst conditions would not have exceeded 25 millirem during that year. The countrywide mean is not expected to have exceeded 3 millirem during the same period. Mainly on account of the still shorter physical half-life of barium 140 the dose from this radioisotope has been considerably smaller. In the absence of further atmospheric nuclear tests, it is to be expected that the future dose from both strontium 89 and barium 140 will be negligible.

Additional Radiation Dose from External Sources

In addition to the dose from isotopes entering the body through the 'food chain', the body tissues are also irradiated from external sources arising from fallout deposited on the ground. In the first year after nuclear tests have occurred the deposited material consists largely of relatively short-lived isotopes, the radioactivity of which decreases markedly in a period of some months, together with a small proportion of caesium 137 which decays slowly. (The strontium 90 in the fallout does not contribute to the external radiation dose since it does not emit gamma-radiation.)

The doses received by the body from this deposited radioactivity have been measured in a number of places and vary from place to place with the amount of the deposit, which varies with the rainfall. It is estimated that during 1963 the inhabitants of areas where the external exposure is highest received about 10 millirem from this source ; the country-wide average being about one-third of this value.

8. Estimated Total Doses to Bone and Bone Marrow from all Components of Fallout

It is concluded that in 1963, children of about one year of age will have incurred the highest radiation dose in bone. The maximum dose which might have been incurred from strontium 90 by individuals in this age-group exposed to the most adverse conditions was derived in Section 6 as being about 140 millirem, while the average dose for this age-group in the population at large was about 20 millirem. When corresponding increments of 75 millirem and 10 millirem are added on account of the contribution from other components of fallout in 1963 (see Section 7 above) the respective totals are 215 millirem and 30 millirem*.

The estimated bone radiation doses from fallout in 1963 are thus considerably below those specified by the Medical Research Council for individual members of the population and for the population as a whole from strontium 90, namely, 540 and 180 millirem/year respectively. Similarly, the radiation dose equivalent to the 'cautionary level' will not have been reached in the bones of any age-group of the general population.

In the absence of further atmospheric nuclear tests the irradiation of bone and bone marrow from strontium 89 and from external radiation due to short-lived materials will be negligible during 1964. By the end of the year the deposition of strontium 90 and caesium 137 should also be decreasing appreciably. Forecasts of the total doses in bone and in bone marrow during 1964 are subject to some uncertainty, mainly because of unpredictable meteorological factors affecting the pattern of fallout. Available evidence, however, suggests that these doses may be of the same order as in 1963, but should decrease thereafter.

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* The total doses to bone marrow from all components of fallout are estimated as being about one-half of the above values.

9. Iodine 131

Levels of the short-lived radioisotope iodine 131 in milk have been below the limit of detection throughout 1963. The possible hazard from exposure to this source has, however, been kept under review.

Iodine 131 becomes concentrated in the thyroid gland and, because it is taken into the body predominantly through milk, the Medical Research Council specified in October 1961* that an acceptable dose would not be exceeded in any age-group of the population unless an average concentration of this radioisotope of 130 pc/litre in milk was exceeded over a period of one year, or higher concentrations were maintained for correspondingly shorter times.

Since this ' acceptable ' level of iodine 131 in milk was specified, further information has become available which indicates that it was unduly cautious. The original figure of 130 pc I-131/litre was specified on the assumption that there might be a substantially greater uptake by the thyroid glands of children in the first year of life than subsequently. An extensive review of more recent data now supports the view that the uptake in young children is no higher than in adults except transiently in the first few days of life. The more appropriate ' acceptable ' level of iodine 131 now appears to be 200 pc/litre as an average intake over a period of one year. It should be noted that the younger age-groups must still be regarded as those at greatest risk, primarily because of their smaller thyroid glands and longer expectation of life.

Signed on behalf of the Committee,
John Cockcroft
Chairman.

February 1964.

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* Statement by the Medical Research Council on radioactive fallout in the light of the resumption of nuclear weapon testing (MRC. 61/1060).

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